इंटरनेट मानक

Disclosure to Promote the Right To Information

Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

"जानने का अधिकार, जीने का अधिकार"
Mazdoor Kisan Shakti Sangathan
"The Right to Information, The Right to Live"

"पुराने को छोड नये के तरफ"
Jawaharlal Nehru
"Step Out From the Old to the New"

IS 13555 (1993): Guide for Selection and Application of 3-Phase A. C. Induction Motors for Different Types of Driven Equipment [ETD 15: Rotating Machinery]

"ज्ञान से एक नये भारत का निर्माण"
Satyanarayan Gangaram Pitroda
"Invent a New India Using Knowledge"

Act Number 22 of 2005
The Indian Parliament
RIGHT TO INFORMATION

Made Available By
Public.Resource.Org

"ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है"
Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

BLANK PAGE

BRUTUM FULMEN
IGNORANTIA JURIS NON EXCUSAT
PROTECTED BY COPYRIGHT

IS 13555 : 1993
(Reaffirmed 2004)

भारतीय मानक

विभिन्न प्रकार के चालन उपस्करों के लिए तीन फेजी ए० सी० प्रेरभ मोटरों के चुनाव और अनुप्रयोग की मार्गदर्शिका

Indian Standard

GUIDE FOR SELECTION AND APPLICATION OF 3-PHASE A. C. INDUCTION MOTORS FOR DIFFERENT TYPES OF DRIVEN EQUIPMENT

UDC 621·313·333·025·3

© BIS 1993

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

May 1993

Price Group 6

Rotating Machinery Sectional Committee, ET 15

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards after the draft finalized by Rotating Machinery Sectional Committee had been approved by the Electrotechnical Division Council.

An electric motor is meant for conversion of electrical energy into mechanical energy. Mechanical energy is required in industries to drive machines such as compressors, cranes, crushers and locomotives and in agriculture to drive irrigation pumps and other farm equipment. The installation sites of machines in industries differ in nature from industry to industry. Installations may be both outdoor or indoor, in humid or in dry weather. Requirements too, differ from industry to industry depending upon a variety of ultimate applications.

In addition to above, there are other important factors such as, characteristics of driving equipment and the equipment to be driven, characteristics of supply system, environmental conditions and the economic considerations for a particular application. Attempt is made in this Guide to enable the user of an electric motor to appreciate the overall situation and thereby make the right selection of the electric motor for a particular application.

This Guide does not include requirements for motors to be used in hazardous area.

Selection of electric motors for different driven equipment requires careful consideration of the various features and characteristics of the motor. General factors involved in motor selection are given in Table 1. Table 2 provides guidance for selection of requirements of a motor. Basic steps to select the motor are listed in Table 3 and guide for selection of induction motors for different applications is provided in Tables 4, 5 and 6.

These tables may prove useful as a check-list in determining the requirements in motor specifications or in considering the motor features required for a new application.

The size chosen shall satisfy the customers on all performance parameters including power factor and efficiency. Optimizing the system efficiency would be the responsibility of the system designer. From the point of view of energy conservation, information on power factor and efficiency would, therefore, be necessary.

Indian Standard

GUIDE FOR SELECTION AND APPLICATION OF THREE-PHASE A.C. INDUCTION MOTORS FOR DIFFERENT TYPES OF DRIVEN EQUIPMENT

1 SCOPE

1.1 This Guide covers selection and application of three-phase induction motors for driving different equipments for industrial and agricultural use.

1.2 The guidance for installation and maintenance of 3-phase induction motors is covered in IS 900 : 1965 'Code of practice for installation and maintenance of induction motors *(revised)*'.

2 REFERENCE STANDARDS

The list of Indian Standards given in Annex A are necessary adjuncts to this Guide.

3 TERMINOLOGY

For the purpose of this Guide, the definitions given in IS 1885 (Part 35) : 1973 and IS 325 : 1978 shall apply.

4 EXCHANGE OF INFORMATION

The engineers responsible for the selection of electric motor for the given application (driven equipment) should be aware of the exact duties, locations and conditions under which it is expected to operate. This information should be exchanged with the motor manufacturer for proper matching between the load and the prime mover for attaining maximum efficiency and safety of the installed equipment and the installation as well.

5 CHARACTERISTICS OF DRIVEN EQUIPMENT

5.1 The following particulars of the driven machine must be known exactly for selecting the motor suitable for the specific application :

a) Name;
b) Brief description of the equipment;
c) Power required in kW;
d) Rated speed of operation;
e) Torque speed characteristics of the load;
f) Type of duty;
g) Moment of inertia of the rotating parts; and
h) Method of drive, whether directly coupled, belt, gear or chain driven which contribute to the mechanical efficiency of the drive.

5.2 Determination of Full Load Output of Driven Machine

Mechanical input required by the driven machine should be calculated accurately taking into account efficiency of the driven machine itself and the efficiency of the system (including that of the coupling used). The formulae of calculating motor output '*P*' are given in Annex B.

5.3 Load-Torque Characteristics

5.3.1 *Torque-Speed Characteristics*

The curve giving the relationship between torque and speed of the driven machine plotted as a function of the speed within the particular range is required for determining the starting and braking conditions. The various types of loads occurring in practice are broadly classified into four groups shown in Fig. 1. These are :

a) The torque remaining practically constant throughout the speed; the power varies in proportion to the speed. These characteristics are typical for hoisting equipment, reciprocating pumps and compressors operating against a constant pressure; soot blowers, rolling mills, belt conveyors, mills without fan action, and machine tools with a constant cutting force.
   These characteristics are also typical for machines which should overcome the gravity, sometimes also for shears, punching machines and wood grinders.
b) The torque increasing in proportion to the speed; the power in proportion to the square of the speed.
   These characteristics are typical for machines smoothening cloth and paper, calendering machines, etc.
c) The torque increasing in proportion to the square of the speed; the power in proportion to the third power of the speed.
   These characteristics are typical for centrifugal pumps, fans and reciprocating machines feeding into an open pipe system.
d) The torque decreasing inversely proportional to the speed; the power remaining constant.
   These characteristics are important for automatic control process only, for example, for lathes and similar machine tools, winders and wood peeling machines.

5.4 Moment of Inertia

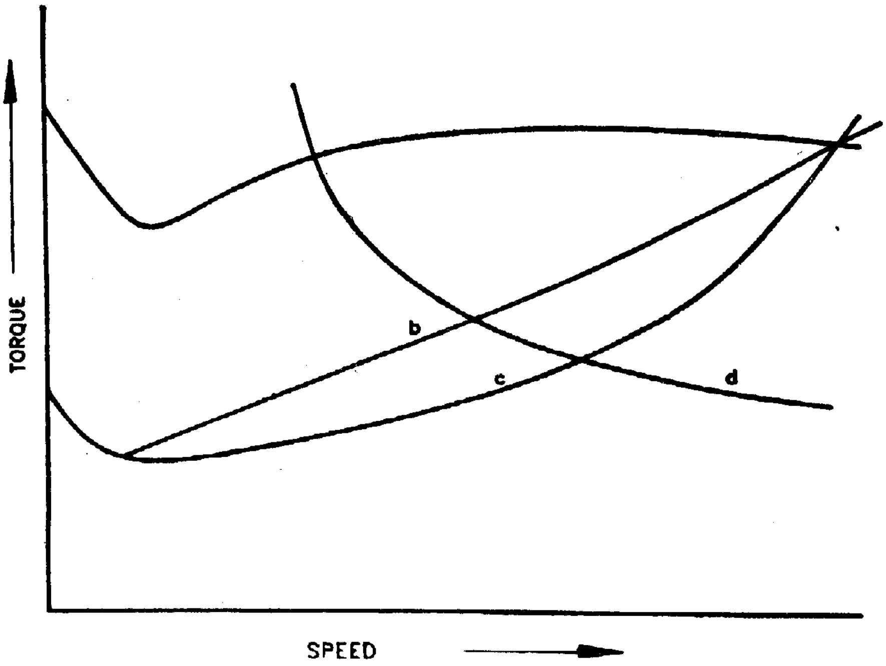
5.4.1 The moment of inertia of the driven machines (GD^2) is determined in case of homogenous bodies, by knowing the weight (of rotating parts) G in kg and diameter of gyration D.

The moment of inertia of the rotating parts of the driven machine in kgfm^2 referred for the motor speed must be known for evaluating the starting and braking conditions:

GD^2 (of the driven machine)
referred to Motor Speed n

$$\frac{(GD^2 \text{ (of the driven machine) x (Speed of driven machine)}^2}{n^2}$$

Total GD^2, referred to motor shaft is then,



Nomenclature :

Variation of torque in relation to speed :

a) Constant torque ,
b) Increasing torque in linear relation,
c) Increasing torque in square relation, and
d) Decreasing torque.

FIG. 1 TYPICAL TORQUE SPEED CHARACTERISTICS OF DRIVEN MACHINE

GD^2 (total) = GD^2 (Motor) + GD^2 (Driven machine); referred to motor speed n.

NOTE — It is a common practice to use $J = \frac{GD^2}{4}$ as the term for moment of inertia. While specifying the data for the mechanism, it shall be clarified which information is being given.

6 SELECTION OF ELECTRIC MOTORS

6.1 Type of Motor

6.1.1 Where the primary requirement is for a constant speed drive, the first choice is almost always the cage-type induction motor, mainly on account of its simplicity, robust construction and low initial cost.

Although much has been said in the past about starting of motors through voltage or winding connection control (resistance, star/delta and auto-transformer starters), much larger and generally stiffer supply systems are now available, which permit the use of 'direct on-line start' of motors. This has made the designs simpler and efficient. Therefore, unless absolutely necessary, a direct on-line start is to be preferred and as stated in **4**, the information on duties and performance desired out of the mechanism, shared freely with the motor manufacturer, so that an efficient motor could be selected out of the larger variety of designs now possible. A motor with a higher value of starting current may be more efficient.

Relatively minor modifications to the rotor windings (using deep bars, or double-cage designs) enable machines to have significantly better starting performance than the simple cage machine. For instance, low starting current designs are readily available as are high torque designs in which the breakaway torque of the machine exceeds twice the full-load torque. Special designs, particularly those based on the double cage construction, enable other combinations of torque and current to be achieved to match the particular requirements of the drive and supply system.

Although primarily a fixed speed machine, the cage type induction motor can easily be wound to give two distinct synchronous speeds by adopting either of the following methods :

a) Appropriately connecting the stator winding;
b) Accommodating two separate windings in the stator, wound for differing number of poles and energized as required; and
c) Utilizing pole-amplitude-modulation (PAM) techniques.

6.1.2 Where the drive requires an adjustable speed value of one or more fixed speeds, the choice of motor type widens considerably. Slip-ring induction motors with rotor resistance control are often adopted for intermittent duties (for instance, crane or hoist drives) where the inherently high losses of the equipment at low speed are acceptable, whereas on drives where the efficiency is important, the commutator motor is the more usual solution.

NOTE — The availability of thyristors has made it possible the use of d.c. machines on a wider variety of industrial drives. Hitherto, these had been very largely confined for certain specialist areas such as steel works, where the large rolling mill drive was a typical application for Ward-Leonard set. The ease with which a normal a.c. supply can now be converted by static rectifier system to an adjustable volatge d.c. supply has led to the increasing use of thyristor-fed d.c. motors for drives requiring a wide speed range.
Thyristors are also used in the various types of static frequency converter sets, the variable frequency output being fed to induction motors, the speeds of which are then controlled in accordance with the converter output frequency.

6.2 Mounting and Frame Number (Mounting Dimensions)

6.2.1 The simplest and the least expensive method of mounting an electric motor is the foot mounting. There are other types of mounting, such as flange mounting, (face mounting bolted directly to the machine) which are also quite commonly used. The position of the base mounting holes (*see* IS 1231 : 1974) with reference to each other and to the location of the shaft are quite important in case of foot mounted motors. Similarly, it is the pitch circle diameter of mounting holes, the spigot diameter and location of the shaft from the face of the flange, which are important in flange or face mounted motors (*see* IS 2223 : 1983).

6.2.2 The fixing dimensions and the shaft extension details have been standardized in IS 2223 : 1983 and outputs are also assigned to the frames. However, the overall dimensions are not standardized, therefore complete interchangeability is not guaranteed. Though the main fixing dimensions are usually sufficient to allow replacement by motors of different manufacture, it is recommended that user may specify the maximum permissible overall dimensions of the motors for applications where the motors are required to be mounted in restricted space.

Apart from the fixing dimensions (*see* IS 2223 : 1983), the standard specifies the accuracies of mounting flanges such as concentricity and perpendicularity and accuracies of shaft runouts, as these are quite important in the case of flange mounted motors. There are two classes of accuracies, normal and precision; of which the precision class is generally on demand for special purposes.

NOTE — Certain mounting arrangements are possible only up to certain frame sizes. It is, however, hoped that some day various manufacturers of motors would join together and evolve a common standard of mounting dimensions linked with rating as in IS 1231, so that the users of large rating motors can interchange motors of one make with other.

6.3 Enclosures of Motors

6.3.1 The primary function of the motor enclosure is to provide the required degree of protection to the vital part of motor as well as to the working personnel. The detailed information on degrees of protection provided by enclosures is given in IS 4691 : 1985. The two basic types of frame constructions are totally enclosed type and open type, with additional protection against dripping and splashing of liquids, dusts, etc. Depending upon the location of the machine a suitable enclosure has to be chosen. In practice, it is usually found that, where normal conditions exist in a factory, simple drip-proof (IP 22) enclosures are by far the most suitable and if positioned sensibly, will give all the protection required with the minimum of interference to ventilation of machine. In fertilizer and chemical plants, the enclosures should provide mechanical as well as chemical protection to the motors with the minimum of interference to ventilation of machine.

The totaly enclosed motor (protection IP 54), whilst of course giving perfect mechanical protection, is larger in size and costs considerably more than its standard screen-protected counterpart, and it is very much open to question whether its installation is justified in a factory where the atmosphere and general humidity are normal.

6.3.2 It is appreciated that there are many situations in factories, where the working conditions are between the two extremes, one definitely necessitating totally enclosed motors and second those approaching clean laboratory conditions, where ordinary screen protected versions will operate successfully. In such situation, there are many other types of motor enclosures which will operate very efficiently. For example, piped ventilated motors method of cooling IC 37 of IS 6362 : 1971 are very suitable for conditions encountered in saw mills, though in extreme cases these usually have to be located near the outside walls of a building to facilitate the installation of the intake and outlet ventilation pipes.

6.3.3 Table 1 gives the recommendations for selection of motors for different application. Table 2 gives the steps for selection of requirements of a motor.

6.4 Supply System and Ambient

6.4.1 In general, a.c. and d.c. are two supply systems. The d.c. system is used for specific requirements such as traction, steel mill drives, textiles drives etc. In the a.c. system frequencies generally standardized are 50 Hz and 60 Hz. In India 50 Hz frequency is prevalent. Furthermore, there are two types of available a.c. voltage supplies, single phase and three phase. The single phase voltage is 240 volts and the three phase line to line voltages are standardized as preferred values 415 volts, 3.3 kV, 6.6 kV and 11 kV.

6.4.2 It is not possible to maintain voltages and frequencies at their rated values. Therefore, the Indian Electricity Rules 1956, permits certain variations. The parameters such as speed-torque characteristics, efficiency, power factor, slip, etc, depend upon voltage and frequency.

6.4.3 Often the user has a choice of supply to which a motor can be connected. In principle, motors can be satisfactorily manufactured for a wide range of voltage levels. Although the higher the voltage the larger and more expensive the motor. These differences are generally small in comparison with the levels, so that the motor supply voltage is generally settled by considerations other than the motor cost alone. In such circumstances, it is important to bear in mind that it is difficult to manufacture small motors for high voltages. Outputs below 100 kW at 3.3 kV, below 200 kW at 6.6 kV and below 1 000 kW at 11 kV pose difficulties in the manufacture of quality motors.

6.4.4 The standard motors (*see* IS 325 : 1978) are designed to operate under voltage fluctuations up to ± 6% and ambient temperature up to 40°C in conditions of wider voltage fluctuations and ambients above 40°C, these motors are required to be derated. The derating factors may be obtained from motor manufacturers. However, it is necessary to give the actual voltage and ambient condition to the motor manufacturer, so that motor can be designed/selected suitably.

6.5 Speed

6.5.1 Induction motors are limited in their speeds available as these are determined by the number of 'poles'. A two-pole motor has a synchronous speed of 3 000 rpm, 4-pole has 1 500 rpm, 6-pole has 1 000 rpm and so on, the formula being :

Speed = 6 000/No. of poles (rev/minute)
(for 50 Hz supply)

The most common are 4-pole and 6-pole motors for industrial application having the best all round characteristics. The practical limit of low speed is 500 rpm (synchronous) and when lower speeds are needed, it is economical to consider the use of an integral gear box and motor unit.

NOTE — 'Synchronous' speed is never attained in practice, the motor always runs slower by an amount known as the 'slip'. The slip at full load varies with the kW rating, type of motor and number of poles. It normally varies between 0.5 percent to 10 percent.

The slip can be determined by using the following formula :

$$\text{Slip} = \left(\frac{\text{Synchronous speed} - \text{Actual speed}}{\text{Synchronous speed}}\right) \times 100$$

6.5.2 It is not necessary to emphasize that, if a choice of speed is possible, it is preferable to use 4-pole motor, next a 6-pole and so on. The motors having larger number of poles take up more space, are more expensive and are deficient in efficiency and power factor compared with the lower polarities.

2-pole motors are not recommended where the high speed is not essential as they tend to be noisy and take more current while starting.

6.6 Output, Torques and Type of Duty

6.6.1 Starting torque required may vary between 10 percent to 250 percent of full load torque depending upon the type of machine being driven. Starting torque may vary for a given motor because of frequency of starts, temperature-rise, terminal voltage, series connected inductive loads, etc and such variables should be taken into account. The motor torque must be well above that required by the driven machine at all points up to full speed. The greater the excess torque the more rapid the acceleration (*see* Fig. 2).

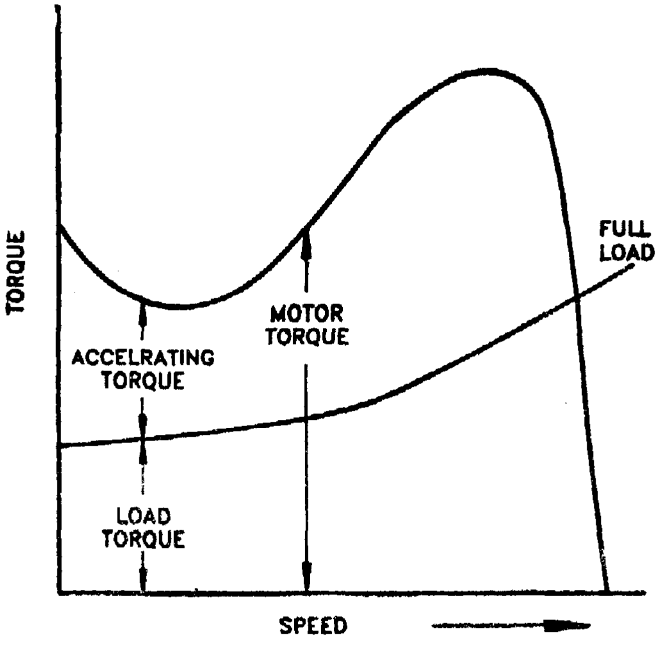


FIG. 2 TYPICAL TORQUE SPEED CHARACTERISTICS OF MOTOR

Table 1 Motor Selection and Application

(*Clause* 6.3.3)

Sl No.	Industrial Locations	Air Borne Contaminant or Hazard	Recommended Dergree of Protection Provided by Motor Enclosure (*See* IS 4691 : 1985)		Special Treatment
1	General Industrial Installations, Non-explosive atmosphere	a) Clean, dry air	Open NP/NP	IP 21/IP 23	
		b) Dripping water or high humidity	Dripping or splash proof	IP 22/IP 23	Space heater or low voltage heating of winding during shut-down
		c) Splashing water	Splash proof	IP 23	Space heater or low voltage heating of winding during shut-down
		d) Abrasive dust/conducting dust	TEFC or pipe ventilated or source of clean air available	IP 54	Special treatment to stator winding
		e) Textile dust or fibre Sticky or oily dust	TE/TEFC TE or pipe ventialated or source of clean air available	IP 44 IP 44/IP 54	Clean flow construction
2	Metal working machinery Non-explosive atmospheres	Abrasive or metallic dust also oil mist	TE/TEFC or pipe ventilated or source of clean air available	IP 44/IP54	Turmoute seal case of magnetic dust
3	Chemical plant Non-explosive atmosphere	Corrosive dust vapour, mist or gas	TE/TEFC or pipe ventilated or source of clean air available CACA/CACW (for higher ratings)	IP 44/IP 54	Space heater, drain plugs, anti-corrosive treatment, epoxy paint
4	Marine application	Saline atmosphere splashing of water	TEFC, Hoseproof Deck water tight	IP 44/IP 55 IP 56	Anti-corrosive treatment, epoxy paint
5	Outdoor installation	Rain or exposure to wind driven dust, rain and snow	TEFC	IP 44	Drain plugs
		Corrosive dust or vapours	Same as 3 above	Same as 3 above	Drain plugs
		Explosive gas or dust	do	do	Canopy

Table 2 Motor Selection Guide and Check List for Specification

(*Clause* 6.3.3)

- Electric Motor Dirve
  - Standard
    - Performance
    - Dimensions
    - Construction and Mounting
    - Enclosure and Degree of Protection
    - Method of Cooling
    - Vibration Level
    - Noise Level
    - Electrical Features
      - Power Supply
        - Voltage and Tolerance
        - Frequency and Variation
        - Combined Variation of Voltage and Frequency
        - Type of Supply 3-Ph 3 Wire or 3-Ph 4 -Wire
      - Motor Type
        - Squirrel Cage
          - Single Speed
          - Multi Speed
            - Const Torque
            - Const kW
            - Variable Torque
        - Wound Rotor
      - Characteristics
        - Speed
        - kW
        - Torque
        - Current Slip
        - Efficiency Power Factor
        - Overload
      - Duty Cycle
        - Speed
        - Method of Starting and Acceleration Time
        - Method of Braking
        - Method of Reversal
        - *Gd* of Load
        - Voltage of Frequency During Start
      - Ambient Condition
        - Temperature
        - Location of Motor on Machine Tool
          - Open
          - Enclosed
        - Altitude
        - Area of Operation
          - Corrosive
          - Hazardous
          - Non-Hazardous
    - Mechanical Features
      - Frame
        - Enclosure
          - Type of Protection
          - Type of Cooling
        - Mounting
          - Horizontal or Vertical
            - Foot
            - Flange
            - Face
        - Dimensions
          - Fixing
          - Overall
          - Accuracies on Shaft Runout Spigot Runout and Face Runout
        - Position of Terminal Box
      - Insulation
        - Class 'A'
        - Class 'E'
        - Class 'B'
        - Class 'F'
        - Class 'H'
      - Bearing
        - Greasing and Lubrication
        - Protection
          - Sealed
          - Shielded
        - Type
          - Ball
          - Roller
          - Sleeve
        - Load
          - Radial
          - Axial
          - Thrust
      - Shaft
        - Extension
          - Fastening
            - Flat
            - Keyway
            - Taper
            - Spline
            - Thread
            - Special
          - Single
          - Double
          - Diameter
          - Length
            - Standard or Special
        - Material
          - Steel
          - Stainless Steel
          - Special
        - Axial Play
        - Type of Drive
      - Auxiliaries
        - Clutch Cable
        - Break Box Gland
        - Compression
        - Greasing
        - Space Heater
        - Thermal Protection
        - Lead Connection
        - Rating Plate
        - Plugging Switch
        - Fault Level
      - Miscellaneous
        - Vibration Level
          - Normal
          - Precision A, B or C
          - Special
        - Noise Level
        - Speical Finish/Paint

6.6.2 Where the load to be carried by the motor is not constant but follows a definite cycle, a graph showing load in kW Vs time enables determination of peak output as well as the root-mean square kW, which indicates the proper motor rating from point of temperature rise of windings.

6.6.3 The duties required to be performed by three-phase induction motors have been rationalized into nine different types known as S1 to S9 in IS 12824 : 1989. Any application can be classified into one of the above duty types.

6.6.4 When the motors are subjected to frequent starting, the losses which occur during the starting period become appreciable, resulting in overheating of motors. The tendency to fit motors of a larger rating than needed, just to improve application is certainly not recommended for frequent starting.

6.6.5 Frequency reversing by 'plugging' is even more arduous than frequent starting. On a tapping machine most of the energy losses in the motor occur during the reversing period. To minimize these losses the rotor cage is made of special design. It is often an advantage with frequent starting or reversing applications to use a slipring motor with permanently connected external 'buffer' resistance to the rotor circuit. Thus a considerable proportion of the losses which would otherwise occur in the rotor are dissipated in the external resistance, enabling a smaller frame size to be used. Reversing duty motor permit the elimination of mechanical clutch and reversing systems.

6.6.6 Closely related to the problem of starting is the braking of induction motors. Brake motors are employed in applications where frequent starting or reversing service, immediate and exact stopping of machiine tools or instant breaking for safety reasons is required.

6.6.7 For certain applications where peak loads of short duration alternate with periods of light load, it is common practice to employ flywheel as reservoir of energy from which the peak load is obtained. The commonest example of these are the mechanical presses used in presses tool work.

The sudden load which is imposed when the clutch is engaged to turn the gearing and force down the ram of the press would require a very large motor if a flywheel were not incorporated. By using a flywheel, the size of the motor can be considerably reduced, as the flywheel supplies most of the peak load. In giving some of its stored energy the flywheel slows down (about 10 percent) and during the next few seconds after the stroke of the press is completed the motor accelerates the flywheel back to full speed. The flywheel thus has the effect of spreading the load on the motor over a longer period. For this duty special motors are required which develop their rated output at approximately 8-10 percent slip. These are in larger frames than normal and are fitted with high external 'buffer' resistance permanently connected in the rotor circuit. Thus most of the rotor losses are dissipated externally and the size of motor is reduced.

6.6.7.1 Flywheels are sometimes misapplied to machines whose working cycle is so short as to provide no chance for the flywheel to lose speed with the load and regain it during the rest of the cycle, for example, a high speed reciprocating press. In such cases a flywheel should not be used, only a motor of adequate output is recommended.

NOTE — When ordering motor for fluctuating loads which are to use a flywheel of stated inertia, details of the energy absorbed in each stroke, the duration of the stroke and the number of strokes/min should be stated to enable the motor manufacturer to calculate the correct output kW and slip-speed.

6.7 Electrical Insulations

6.7.1 The classification of insulations on the basis of their thermal evaluation is given in IS 1271 : 1985. There has been considerable changes in electrical insulation in recent years. Standard machines are usually class B (130°C) or class F (155°C), and with class H (180°C) for special. The main developments which have given rise to potential increase in motor temperatures are in electrical slot insulation, including sheet insulating materials, sleevings, impregnating varnishes and winding wire enamels. As machine outputs are primarily limited by the permissible temperatures at which their windings can be operated, the use of the higher temperature insulation enables more output to be obtained from a given volume of active material, that is, from a given frame.

6.7.2 With the development of production machines requiring increased power (kW) the motor space problem has become significant. Generally, a machine tool of relatively the same physical size today requires to be driven by a motor of output (kW) rating 50 percent higher than before. Use of higher class insulation has helped in reducing the frame size and thus accommodating the motor in restricted space.

6.7.3 The increased application of automation in industry has resulted in an increased demand for motors with frequent/stop duty cycle. It is often impossible for the user to say in advance exactly what the motor duty cycle he requires will be, with the result that standard motors have often failed in service after a relatively short period of operation. By using Class F insulation on the standard machines, therefore, more severe thermal stressing of the stator winding may be allowed.

The thermal characteristics of Class F insulation may be used to considerable advantage for motor operating under abnormal operating conditions such as wide voltage and frequency fluctuations, unbalance in supply voltage, high ambient temperatures, restricted ventilation, mechanical overloading, severe duty cycles such as frequent starting, prolonged starting, plugging, etc.

5.8 Noise Levels

Noise has become an increasingly important factor in the design and application of mechanical devices because of the growing realization that exposure of the workers to a high noise level over a long period may cause undesirable effects, including hearing deficiency or damage.

IS 12065 : 1987 covers limits for sound pressure and sound power levels of three-phase induction motors.

6.9 Vibration Limits

Vibration is bound to exist in any rotary system to a greater or lesser degree and the electric motor is no exception. The limits of vibration level and the methods of measurement have been specified in IS 12075 : 1987. Two classes of vibration levels are specified, one for normal use and the other for precision use.

Table 3 Selection of Motors for Special Applications

(*Foreword*)

Basic Steps to Select the Motor		
Step 1	Power supply	ac or dc, its voltage and frequency condition
Step 2	Output (kW) rating	Steady or varying loads, rms value, speed torque curves of motors and loads, starting, and running characteristics, stable and unstable working regions; light, moderate and heavy starting torque requirement for various applications. High inertia loads requiring prolonged starting time. High slip motors for power punch presses with flywheels. Duty cycles S1 to S8 (*see* IS 12824 : 1989).
Step 3	Speed	Economy of 4 pole motors, possibility of obtaining desired speed of driven equipment by proper selection of pulleys, gears/couplings.
Step 4	Enclosure	To provide desired degree of protection by enclosure (IP XX as per IS 4691) depending upon the environmental conditions. Typical enclosures DP and TEFC etc.
Step 5	Environments	Unusual service conditions constituting exposure of the motor to : a) chemical fumes b) combustible dust (metallic dusts like magnesium) c) dust of explosive d) abrasive and/or conductive dust e) lint or fluff as encountered in textile mills f) flammable or explosive gases, hazardous location g) ambients above 40°C or below 0°C h) salt air j) abnormal shock or vibration from external source k) abnormal shock or vibration from internal source m) external mechanical loads involving abnormal thrusts or overhang n) radiant heat p) nuclear radiation q) vermin infestation or atmosphere conducive to growth of fungus r) oil vapour s) very damp or dry place t) altitudes greater than 1 000 m u) specially treated/protected motors required for such abnormal environmental conditions
Step 6	Operating conditions	Unusual operating conditions are departure from rated voltage and/or frequency. Poorly ventilated rooms/pits boxes. Unbalanced supply voltage. Operation when subjected to torsional impact loads. Operation when subjected to frequent starting, reversing or electric braking (onerous duty). An out of phase bus transfer. All such abnormal operating conditions are to be carefully studied to arrive at a proper selection of motor.
Step 7	Mounting	Various types with horizontal and vertical shafts. Type A, B, C flanges etc (*see* IS 1231, 2223 and 2254).
Step 8	Connection to load	Flexible or solid coupling, hydraulic coupling (traction type or scoop controlled), pulley and belt, pinion etc.
Step 9	Mechanical features	Special shafts, splined shaft, special flanges mounting, centre heights etc.
Step 10	Motors for special applications and special industries	Motors for machine tools, cranes, lifts, power punches, lower noise, looms, cards, spinning frames, centrifuges etc. Special industries motors for textile mills, rubber, fertilizers, mining, petrochemicals, cement, steel plants, nuclear power station, paper, marine duty etc.

Table 4 Guide for Selection of Induction Motor for Various Applications

(*Foreword*)

Application	Type of Motor Recommended	Check Points	Remarks
Pump centrifugal or reciprocating	Squirrel cage or slipring. (IS 325 : 1978 and IS 1738 : 1975)	Normally started with close valve conditions	If star-delta starting with open valve is required, please consult motor manufacturer giving starting torque requirements.
Compressors Rotary	Squirrel cage or slipring (IS 325 : 1978)	Unloaded starting	In case a squirrel cage motor is to be used to drive the reciprocating compressor.
Reciprocating	Slipring or squirrel cage (IS 325 : 1978)	Starting with partial load	Please consult motor manufacturer giving starting torque requirement and method of starting.
Centrifugal fans	Squirrel cage or slipring (IS 325 : 1978)	Started with closed chamber or closed valves.	When a squirrel cage motor is used, the acceleration time should not exceed 15 seconds on direct-on-line otherwise please consult motor manufacturers giving value of fan inertia.
Blowers	Squirrel cage or slipring except 2-pole motors (IS 325 : 1978)	Starting with valve closed.	When a squirrel cage motor is used, the acceleration time on direct on-line starting should not exceed 15 seconds. Otherwise (and also when 2-pole motors are to be used), please consult motor manufacturers giving starting torque requirements and inertia of fans with reference to motor speed.
Agitator and mixers (for liquids)	Squirrel cage or slipring (IS 325 : 1978)	Light starting duty	do
Cranes/Hoists	High torque squirrel cage or slipring (IS 325 : 1978)	-	Please furnish the following to the motor manufacturer : i) No. of starts, plug stops inching/reversals per hour. ii) Cyclic duration factor. iii) Method of braking mechanized/Dynamic plug stop/plug resource. iv) Starting and pullout torque. v) Load inertia referred to motor speed.
Lifts	Squirrel cage with smooth uniform acceleration and quiet running.	-	do
Pulley drive	Squirrel cage or slipring (IS 325 : 1978)	Belt tension	Please furnish the following to the motor manufacturers : i) Type of Belt, Flat or V Belt and Number ii) Diameter of pulley on motor shaft iii) Breadth of pulley on motor shaft iv) If the centre of the hub coincides with the centre of the rim of the pulley. If not, the displacement between the two centres may be furnished. v) Weight of pulley in motor side in kg. vi) Inclination of pulley system from the horizontal.

NOTE — For proper design of the motor, it is essential that load torque curve and inertia referred to motor speed are supplied to the motor manufacturer.

Table 5 Guide for Selection of Induction Motors for Heavy Starting Duty and High Peak Load Applications

(*Foreword*)

Application	Type of Load	Special Characteristics of Motor	Type of Motor	Remarks
Line Shafts	Heavy starting	Started on load Normal starting torque required, 200% FLT	High torque squirrel cage or slipring	Please furnish the following details to the motor manufacturer : i) Complete load characteristics ii) Ambient temperature iii) Starting and pull-out torque iv) Number of starts/stops, inchings and reversal per hour. v) Method of braking, if any Mechanical/dynamic plug stop/plug reverse
Pulverisers Power mixers	do	do	do	
Flour, Paper and Rubber mills	High peak loads	Pull-out torque 200% to 250 % FLT	High torque squirrel Cage or slipring	
Rolling mills				
Strokers				
Circular saws				
Chippers				
Beaters				
Ball mills				
Crushers (without flywheel)				
Hammer mills (without flywheel)				
Hydro-pulpers				

NOTE — For proper design and the motor, it is essential that load torque curve and inertia referred to motor speed are supplied to the motor manufacturer.

Table 6 For Selection of Induction Motors for High Torque and High Slip Application

(*Foreword*)

Application	Type of Load	Special Characteristics of Motor	Type of Motor	Remarks
(All with flywheels)	High peak loads	Heavy starting, high full load slip	High slip, high torque squirrel cage or slipring	Please furnish the following data to the motor manufacturer: i) Inertia of load and flywheel, referred to motor speed. ii) Number of working strokes per minute iii) Energy absorbed per blow iv) Duration of blow v) Starting and pull-out torque requirements vi) Continuous or intermittent service duty/class
Crushers				
Pallet presses				
Punch presses				
Power hammers				
Riveting				
Machines				
Rolling Mills				

NOTE — For proper design and the motor, it is essential that load torque curve and inertia referred to motor speed are supplied to the motor manufacturer.

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Titles*
325 : 1978	Three-phase induction motor (*fourth revision*)
1231 : 1974	Dimensions of three-phase foot-mounted induction motors (*third revision*)
1271 : 1985	Thermal evaluation and classification of electrical insulation (*first revision*)
1885 (Part 35) : 1973	Electrotechnical vocabulary : Part 35 Rotating machinery
2223 : 1983	Dimensions of flange mounted ac induction motors (*second revision*)
2254 : 1985	Dimensions of vertical shaft motors for pumps (*second revison*)
4691 : 1985	Degrees of protection provided by enclosures for rotating electrical machinery (*first revision*)
6362 : 1971	Designations of methods of cooling for rotating electrical machines
7538 : 1975	Three-phase squirrel cage induction motors for centrifugal pumps for agricultural application
12065 : 1987	Permissible limits of noise level for rotating electrical machines
12075 : 1987	Mechanical vibration of rotating electrical machines with shaft height 56 mm and higher-measurement, evaluations and limits of vibration severity
12824 : 1989	Types of duty and classes of ratings assigned to rotating electrical machines.

ANNEX B

(*Clause* 5.2)

FORMULAE FOR CALCULATING MOTOR OUTPUT

a) Linear motion :

$$p = \frac{F \times V}{102 \times eff.} \text{ (kW)}$$

where

F = useful load in kgf,

V = speed in metres/second,

eff. = mechanical efficiency of the drive, and

1 kW = 102 kgf m/sec.

b) Rotary motion :

$$P = \frac{M \times n}{975 \times eff.} \text{ (kW)}$$

where

M = torque in kgf

n = speed in rev/min.

c) Pumps :

$$P = \frac{1\,000 \times V \times \text{Sp Gr} \times h}{102 \times eff.} \text{ (kW)}$$

where

V = discharge in m^3/second

Sp Gr = specific gravity of the liquid to be pumped, and

h = delivery and resistance head in mwg.

d) Lifts where the cage or cabin weight and half of the useful load is usually balanced by counterweights :

$$P = \frac{F \times V}{2 \times 102 \times eff.} \text{ (kW)}$$

where

F = useful load in kgf, and

V = speeds in m/sec.

e) Fans :

$$P = \frac{V \times P}{102 \times eff.} \text{ (kW)}$$

where

V = air delivery in m^3/sec

P = air pressure in kgf/m^2 (mwg) at the outlet.

f) Varying duties S3 and S6 (*see* IS 12824 : 1989) where the losses occurring during starting are negligible, the equivalent S1 rating load may, therefore, be expressed as a root mean square kW output, or

$$\text{kW (rms)} = \left[\frac{(\text{kW}1)^2 t_1 + (\text{kW}2)^2 t_2}{K t_0 + t_1 + t_2 + \ldots\ldots\ldots\ldots\ldots\ldots} \right]^{1/2}$$

where

kW (rms) = equivalent S1 load

kW1 = equivalent kW in first interval of duty cycle, carried for time t_1,

t_1+t_2 = total duty cycle time in seconds,

K = constant for duty cycle time at zero speed which is approx,
1/4 for TEFC motors (cooling IC41 as per IS 6362 : 1971), and
1/3 for open motors (Cooling IC01 as per IS 6362 : 1971); and

t_0 = time of duty cycle of zero speed.

Standard Mark

The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act, 1986* and the Rules and Regulations made thereunder. The Standard Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well defined system of inspection, testing and quality control which is devised and supervised by BIS and operated by the producer. Standard marked products are also continuously checked by BIS for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act, 1986* to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Copyright

BIS has the copyright of all its publications. No part of these publications may be reproduced in any form without the prior permission in writing of BIS. This does not preclude the free use, in the course of implementing the standard, of necessary details, such as symbols and sizes, type or grade designations. Enquiries relating to copyright be addressed to the Director (Publications), BIS.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are any reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Handbook' and 'Standards Monthly Additions'. Comments on this Indian Standard may be sent to BIS giving the following reference:

Doc : No. ET 15 (3160)

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones : 331 01 31, 331 13 75

Telegrams : Manaksanstha
(Common to all offices)

Regional Offices :	Telephone
Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg NEW DELHI 110002	331 01 31 331 13 75
Eastern : 1/14 C. I. T. Scheme VII M, V. I. P. Road, Maniktola CALCUTTA 700054	37 84 99, 37 85 61 37 86 26, 37 86 62
Northern : SCO 445-446, Sector 35-C, CHANDIGARH 160036	53 38 43, 53 16 40 53 23 84
Southern : C. I. T. Campus, IV Cross Road, MADRAS 600113	235 02 16, 235 04 42 235 15 19, 235 23 15
Western : Manakalaya, E9 MIDC, Marol, Andheri (East) BOMBAY 400093	632 92 95, 632 78 58 632 78 91, 632 78 92

Branches : AHMADABAD. BANGALORE. BHOPAL. BHUBANESHWAR. COIMBATORE. FARIDABAD. GHAZIABAD. GUWAHATI. HYDERABAD. JAIPUR. KANPUR. LUCKNOW. PATNA. THIRUVANANTHAPURAM.

Printed at New India Printing Press, Khurja, India